



DECLARATION

In the matter of U.S. patent application No. 10/523,807
in the name of AICHI STEEL CORPORATION

I, the undersigned, Yukie KOJO, of 1-2-16, Tennou, Ichinomiya-shi, Aichi
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sincerely declare as follows:

1. I am well acquainted with the English and Japanese languages and am competent to translate from Japanese into English.
2. I have executed with the best of my ability, a true and correct translation into the English language of the Japan priority application No. 2003-199533 with the filing date of 18 July, 2003.

Dated,

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Signature:

Yukie Kojō



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[Document] Description 1

[Document] Figures 1

[Document] Abstract 1

[Name of Document] SPECIFICATION

10 [Title of the Invention] THREE-DIMENSIONAL MAGNETIC
BEARING SENSOR AND MAGNETO-IMPEDANCE SENSOR DEVICE

[Claims]

[Claim 1] A three-dimensional magnetic bearing sensor
constituted by using a magneto-impedance sensor device with
15 an electromagnetic coil, which comprises said
electromagnetic coil having a spiral shape and being made
up of one coil members formed in an elongate groove extending
in an electrode-wiring substrate in a certain direction
and other coil members connecting corresponding upper ends
20 of said one coil members to each other, and a magnetic
sensitive member which is inserted in an insulator filled
in said elongate groove of said electrode-wiring substrate
and to which is applied a high-frequency wave or a pulse
current, thereby outputting a voltage generated in said
25 electromagnetic coil depending on the intensity of an
external magnetic field when the high-frequency wave or
the pulse current is applied,

said three-dimensional magnetic bearing sensor including a first sensor disposed to lie in an X-direction of a base plate, a second sensor disposed to lie in a Y-direction of the base plate, and a third sensor disposed to lie in a Z-direction of the base plate.

[Claim 2] The three-dimensional magnetic bearing sensor according to Claim 1,

wherein said base plate is constituted by a rectangular IC substrate having four side wall surfaces which are orthogonal to each other between adjacent two, and

said third sensor is disposed along one of the side wall surfaces of said IC substrate such that said elongate groove formed in said third sensor is arranged to extend in a direction of thickness of said base plate.

[Claim 3] The three-dimensional magnetic bearing sensor according to Claim 2,

wherein said first sensor and said second sensor are disposed along the adjacent side wall surfaces of said IC substrate such that said elongate grooves formed in said first and second sensors in the lengthwise direction thereof are extended parallel to said adjacent side wall surfaces.

[Claim 4] The three-dimensional magnetic bearing sensor according to Claim 2,

wherein electrodes formed on an upper surface of said third sensor are connected via leads to electrodes formed

on an upper surface of said IC substrate.

[Claim 5] The three-dimensional magnetic bearing sensor according to Claim 3,

wherein electrodes formed at opposite ends of each upper surface of said first sensor and said second sensor are connected via leads to electrodes formed on an upper surface of said IC substrate.

[Claim 6] A magneto-impedance sensor device with an electromagnetic coil, comprising said electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting corresponding upper ends of said one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in said elongate groove of said electrode-wiring substrate and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated in said electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied,

said magneto-impedance sensor device being disposed along one surface of a base plate such that the formed elongate groove is arranged to extend in a direction of thickness of said base plate.

[Claim 7] A magneto-impedance sensor device with an electromagnetic coil, comprising said electromagnetic

coil having a spiral shape and being made up of one coil
members formed in an elongate groove extending in an
electrode-wiring substrate in a certain direction and other
coil members connecting corresponding upper ends of said
5 one coil members to each other, and a magnetic sensitive
member which is inserted in an insulator filled in said
elongate groove of said electrode-wiring substrate and to
which is applied a high-frequency wave or a pulse current,
thereby outputting a voltage generated in said
10 electromagnetic coil depending on the intensity of an
external magnetic field when the high-frequency wave or
the pulse current is applied,

said magneto-impedance sensor device having
electrodes formed on a surface perpendicular to a surface
15 of said electrode-wiring substrate in which said elongate
groove is formed.

[Claim 8] A magneto-impedance sensor device with an
electromagnetic coil, comprising said electromagnetic
coil formed in an elongate groove extending in an
20 electrode-wiring substrate in a certain direction, and a
magnetic sensitive member which is inserted in said
electromagnetic coil and to which is applied a
high-frequency wave or a pulse current, thereby outputting
a voltage generated in said electromagnetic coil depending
25 on the intensity of an external magnetic field when the
high-frequency wave or the pulse current is applied,

said magneto-impedance sensor device having

electrodes formed on a surface perpendicular to one edge of a surface of said electrode-wiring substrate in which said elongate groove and said magnetic sensitive member are formed, said edge being positioned at one end in a direction in which said elongate groove and said magnetic sensitive member are extended.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a three-dimensional magnetic bearing sensor and a magneto-impedance sensor device, which can be applied to an electronic compass.

[0002]

[Description of the Related Art]

Hitherto, there is known a magnetic sensor wherein a one-piece device holding a magnetic sensitive element, which is surrounded by a gel-like material and is disposed to bridge between electrodes disposed at opposite ends of a rectangular substrate in its lengthwise direction, is inserted and joined in a bobbin around which a detection coil and a feedback coil are wound and arranged in orthogonal relation (see, e.g., Patent Reference 1).

[0003]

Also, a known magnetic bearing sensor comprises mainly a single amorphous magnetic wire to which is supplied a high-frequency current, and a coil for applying a bias magnetic field. A value of a DC current applied to the

coil is changed to detect the value of the DC current which generates a magnetic field having the same magnitude as an external magnetic field to be measured and having a direction reversal to the direction of the external
5 magnetic field to be measured. The magnetic bearing sensor further includes an AC coil supplied with a sine wave current and a DC coil supplied with a DC current, and performs detection through phase comparison between respective sine waves of a sine wave signal of high-frequency impedance
10 monitored from opposite ends of the amorphous magnetic wire and sine-wave current signal supplied to the AC coil. Two or three sets of thus-constructed magnetic sensors are arranged in orthogonal relation to detect a weak magnetic field of earth magnetism, thereby measuring the intensity,
15 orientation and direction of the magnetic field (see, e.g., Patent Reference 2).

[0004]

[Patent Reference 1]

Japanese Unexamined Patent Application Publication
20 No. 2001-296127

(pp. 9-10 and Figs. 6 and 10)

[Patent Reference 2]

Japanese Unexamined Patent Application Publication
No. 11-64473

25 (pp. 4-5 and Figs. 5 and 14)

[0005]

[Problems to be Solved by the Invention]

However, the above-described known magnetic sensor has the following problems because it has the structure that a one-piece device holding a magnetic sensitive element, which is surrounded by a gel-like material and is disposed to bridge between electrodes disposed at opposite ends of a rectangular substrate in its lengthwise direction, is inserted and joined in a bobbin around which a detection coil and a feedback coil are wound and arranged in orthogonal relation. The number of parts and the number of manufacturing steps are increased, and the manufacturing and assembly steps are complicated. Thus, the known magnetic sensor is not adapted for reduction in size and cost of the sensor.

[0006]

The above-described known magnetic bearing sensor also has problems because of the above-described structure. More specifically, it comprises mainly a single amorphous magnetic wire to which is supplied a high-frequency current, and a coil for applying a bias magnetic field. A value of a DC current applied to the coil is changed, and the value of the DC current is detected which generates a magnetic field having the same magnitude as an external measured magnetic field and a direction reversal to that of the external measured magnetic field. The magnetic bearing sensor further includes an AC coil supplied with a sine wave current and a DC coil supplied with a DC current, and performs detection through phase comparison between

respective sine waves of a sine wave signal of high-frequency impedance monitored from opposite ends of the amorphous magnetic wire and sine-wave current signal supplied to the AC coil. Two or three sets of
5 thus-constructed magnetic sensors are arranged in orthogonal relation. However, because the coils of each sensor are wound around a bobbin, the manufacturing and assembly steps are complicated, and the known magnetic bearing sensor is not adapted for reduction in size.

10 [0007]

In view of the problems described above, the inventor has reached the first technical concept of the present invention, which resides in a three-dimensional magnetic bearing sensor constituted by using a magneto-impedance
15 sensor device with an electromagnetic coil, which comprises the electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting corresponding
20 upper ends of the one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in the elongate groove of the electrode-wiring substrate and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated
25 in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied, the three-dimensional

magnetic bearing sensor including a first sensor disposed to lie in an X-direction of a base plate, a second sensor disposed to lie in a Y-direction of the base plate, and a third sensor disposed to lie in a Z-direction of the base plate.

[0008]

Also, the inventor has reached the second technical concept of the present invention, which resides in a magneto-impedance sensor device with an electromagnetic coil, comprising the electromagnetic coil formed in an elongate groove extending in an electrode-wiring substrate in a certain direction, and a magnetic sensitive member which is inserted in the electromagnetic coil and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied, the magneto-impedance sensor device having electrodes formed on a surface perpendicular to one edge of a surface of the electrode-wiring substrate in which the elongate groove and the magnetic sensitive member are formed, the edge being positioned at one end in a direction in which the elongate groove and the magnetic sensitive member are extended.

[0009]

As a result of conducting further researches and developments, the inventor has accomplished the present

invention which can achieve the objects of facilitating manufacturing and assembly steps, realizing size reduction, and enabling the bearing to be detected with high accuracy regardless of the attitude of the magnetic bearing sensor.

5 [0010]

[Means for Solving the Problems]

A three-dimensional magnetic bearing sensor according to the present invention (first invention defined in Claim 1) is constituted by using a magneto-impedance
10 sensor device with an electromagnetic coil, which comprises the electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting corresponding
15 upper ends of the one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in the elongate groove of the electrode-wiring substrate and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated
20 in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied,

the three-dimensional magnetic bearing sensor including a first sensor disposed to lie in an X-direction
25 of a base plate, a second sensor disposed to lie in a Y-direction of the base plate, and a third sensor disposed to lie in a Z-direction of the base plate.

[0011]

In a three-dimensional magnetic bearing sensor according to the present invention (second invention defined in Claim 2), on the basis of the first invention,

5 the base plate is constituted by a rectangular IC substrate having four side wall surfaces which are orthogonal to each other between adjacent two, and

the third sensor is disposed along one of the side wall surfaces of the IC substrate such that the elongate
10 groove formed in the third sensor is arranged to extend in a direction of thickness of the base plate.

[0012]

In a three-dimensional magnetic bearing sensor according to the present invention (third invention defined
15 in Claim 3), on the basis of the second invention,

the first sensor and the second sensor are disposed along the adjacent side wall surfaces of the IC substrate such that the elongate grooves formed in the first and second sensors in the lengthwise direction thereof are extended
20 parallel to those adjacent side wall surfaces.

[0013]

In a three-dimensional magnetic bearing sensor according to the present invention (fourth invention defined in Claim 4), on the basis of the second invention,

25 electrodes formed on an upper surface of the third sensor are connected via leads to electrodes formed on an upper surface of the IC substrate.

[0014]

In a three-dimensional magnetic bearing sensor according to the present invention (fifth invention defined in Claim 5), on the basis of the third invention,

5 electrodes formed at opposite ends of each upper surface of the first sensor and the second sensor are connected via leads to electrodes formed on an upper surface of the IC substrate.

[0015]

10 A magneto-impedance sensor device with an electromagnetic coil according to the present invention (sixth invention defined in Claim 6) comprises:

the electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate
15 groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting corresponding upper ends of the one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in the elongate groove of the
20 electrode-wiring substrate and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied,

25 the magneto-impedance sensor device being disposed along one surface of a base plate such that the formed elongate groove is arranged to extend in a direction of

thickness of the base plate.

[0016]

A magneto-impedance sensor device with an
electromagnetic coil according to the present invention
5 (seventh invention defined in Claim 7) comprises:

the electromagnetic coil having a spiral shape and
being made up of one coil members formed in an elongate
groove extending in an electrode-wiring substrate in a
certain direction and other coil members connecting
10 corresponding upper ends of the one coil members to each
other, and a magnetic sensitive member which is inserted
in an insulator filled in the elongate groove of the
electrode-wiring substrate and to which is applied a
high-frequency wave or a pulse current, thereby outputting
15 a voltage generated in the electromagnetic coil depending
on the intensity of an external magnetic field when the
high-frequency wave or the pulse current is applied,

the magneto-impedance sensor device having
electrodes formed on a surface perpendicular to a surface
20 of the electrode-wiring substrate in which the elongate
groove is formed.

[0017]

A magneto-impedance sensor device with an
electromagnetic coil according to the present invention
25 (eighth invention defined in Claim 8) comprises:

the electromagnetic coil formed in an elongate groove
extending in an electrode-wiring substrate in a certain

direction, and a magnetic sensitive member which is inserted in the electromagnetic coil and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied,

the magneto-impedance sensor device having electrodes formed on a surface perpendicular to one edge of a surface of the electrode-wiring substrate in which the elongate groove and the magnetic sensitive member are formed, the edge being positioned at one end in a direction in which the elongate groove and the magnetic sensitive member are extended.

[0018]

[Operation and Advantages]

The three-dimensional magnetic bearing sensor according to the first invention is constituted by using a magneto-impedance sensor device with an electromagnetic coil, which comprises the electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting corresponding upper ends of the one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in the elongate groove of the electrode-wiring substrate and to which is applied a

high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied.

5 Components of the magnetic field in respective directions are detected by the first sensor disposed to lie in the X-direction of the base plate, the second sensor disposed to lie in the Y-direction of the base plate, and the third sensor disposed to lie in a Z-direction of the base plate
10 detect. An advantage is therefore obtained in that the bearing can be detected with high accuracy regardless of the attitude of the magnetic bearing sensor, and size reduction of the sensor can be realized.

[0019]

15 In the three-dimensional magnetic bearing sensor according to the second invention, on the basis of the first invention, the base plate is constituted by a rectangular IC substrate having four side wall surfaces which are orthogonal to each other between adjacent two, and the third
20 sensor is disposed along one of the side wall surfaces of the IC substrate such that the elongate groove formed in the third sensor is arranged to extend in a direction of thickness of the base plate. An advantage is therefore obtained in that a component of the magnetic field in the
25 direction of thickness of the IC substrate can be detected.

[0020]

In the three-dimensional magnetic bearing sensor

according to the third invention, on the basis of the second invention, the first sensor and the second sensor are disposed along the adjacent side wall surfaces of the IC substrate such that the elongate grooves formed in the first and second sensors in the lengthwise direction thereof are extended parallel to those adjacent side wall surfaces. An advantage is therefore obtained in that components of the magnetic field in directions orthogonal to each other on the IC substrate can be detected, and the same sensor can be used as each of the first sensor and the second sensor for detection of those components, thus realizing reduction in the number of parts.

[0021]

In the three-dimensional magnetic bearing sensor according to the fourth invention, on the basis of the second invention, electrodes formed on an upper surface of the third sensor are connected via leads to electrodes formed on an upper surface of the IC substrate. An advantage is therefore obtained in that connection between the electrodes on the third sensor and on the upper surface of the IC substrate can be easily performed.

[0022]

In the three-dimensional magnetic bearing sensor according to the fifth invention, on the basis of the third invention, electrodes formed at opposite ends of each upper surface of the first sensor and the second sensor are connected via leads to electrodes formed on an upper surface

of the IC substrate. An advantage is therefore obtained in that connection between the electrodes on the first and second sensors adjacent to each other and on the upper surface of the IC substrate can be easily performed.

5 [0023]

The magneto-impedance sensor device with the electromagnetic coil according to the sixth invention comprises the electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate
10 groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting corresponding upper ends of the one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in the elongate groove of the
15 electrode-wiring substrate and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied, the
20 magneto-impedance sensor device being disposed along one surface of a base plate such that the formed elongate groove is arranged to extend in a direction of thickness of the base plate. An advantage is therefore obtained in that a component of the magnetic field in the direction of
25 thickness of the base plate can be detected.

[0024]

The magneto-impedance sensor device with the

electromagnetic coil according to the seventh invention comprises the electromagnetic coil having a spiral shape and being made up of one coil members formed in an elongate groove extending in an electrode-wiring substrate in a certain direction and other coil members connecting
5 corresponding upper ends of the one coil members to each other, and a magnetic sensitive member which is inserted in an insulator filled in the elongate groove of the electrode-wiring substrate and to which is applied a
10 high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied, the magneto-impedance sensor device having electrodes formed
15 on a surface perpendicular to a surface of the electrode-wiring substrate in which the elongate groove is formed. An advantage is therefore obtained in that connection between the electrodes and leads can be easily performed.

20 [0025]

The magneto-impedance sensor device with an electromagnetic coil according to the eighth invention comprises the electromagnetic coil formed in an elongate groove extending in an electrode-wiring substrate in a
25 certain direction, and a magnetic sensitive member which is inserted in the electromagnetic coil and to which is applied a high-frequency wave or a pulse current, thereby

outputting a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied, the magneto-impedance sensor device having electrodes
5 formed on a surface perpendicular to one edge of a surface of the electrode-wiring substrate in which the elongate groove and the magnetic sensitive member are formed, the edge being positioned at one end in a direction in which the elongate groove and the magnetic sensitive member are
10 extended. An advantage is therefore obtained in that connection between the electrodes and leads can be easily performed.

[0026]

[Description of the Embodiments]

15 An embodiment of the present invention will be described below with reference to the drawings.

[0027]

(Embodiment)

As shown in Figs. 1 to 6, a three-dimensional magnetic
20 bearing sensor and a magneto-impedance sensor device with an electromagnetic coil, according to the embodiment, is constituted by using a magneto-impedance sensor device with an electromagnetic coil 3, which comprises the
electromagnetic coil 3 having a spiral shape and being made
25 up of one coil members 31 formed in an elongate groove 11 extending in an electrode-wiring substrate 1 in a certain direction and other coil members 32 connecting

corresponding upper ends of the one coil members 31 to each other, and a magnetic sensitive member 2 which is inserted in an insulator 4 filled in the elongate groove 11 of the electrode-wiring substrate 1 and to which is applied a high-frequency wave or a pulse current, thereby outputting a voltage generated in the electromagnetic coil 3 depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied. The three-dimensional magnetic bearing sensor includes a first sensor 101 disposed to lie in an X-direction of an IC substrate 100 which serves as a base plate, a second sensor 102 disposed to lie in a Y-direction of the IC substrate, and a third sensor 103 disposed to lie in a Z-direction of the IC substrate.

[0028]

First, the magneto-impedance sensor device with the electromagnetic coil (hereinafter referred to as the "MI device"), which constitutes each of the first to third sensors in the embodiment, will be described below.

[0029]

As shown in Figs. 1 and 2, the MI device is constituted by arranging, on the electrode-wiring substrate 1, the magnetic sensitive member 2 for detecting a magnetic field, and an electromagnetic coil 3 having an inner diameter of not larger than 200 μm and arranged around the magnetic sensitive member 2 with only the insulator 4 interposed between them, i.e., in a state where the substrate to which

is fixed the magnetic sensitive member 2 is not present between the magnetic sensitive member 2 and the electromagnetic coil 3. Respective terminals of the magnetic sensitive member 2 and the coil 3 are connected to corresponding electrodes 51, 52 on the substrate 1. When a high-frequency wave or a pulse current is supplied to the magnetic sensitive member 2, the MI device outputs a voltage depending on the intensity of an external magnetic field generated in the electromagnetic coil 3 at that time.

[0030]

In this MI device, since the electromagnetic coil 3 is disposed around the magnetic sensitive member 2 with only the insulator 4 interposed between them, the inner diameter of the electromagnetic coil 3 can be held not larger than 200 μm and the overall size of the MI device can be reduced.

[0031]

Also, in the MI device of this embodiment, the magnetic sensitive member 2 is an electrically-conductive magnetic wire having a diameter of 1 - 150 μm . The electrode-wiring substrate 1 has the groove 11 with a depth of 5 - 200 μm . The electromagnetic coil 3 is made up of one-side patterns 31 which serve as the one coil members of the electromagnetic coil and are arranged to extend spirally or parallel along a groove inner surface 111, and other-side patterns 32 which are arranged at a lower surface of an upper substrate 12 to serve as the other coil members of the electromagnetic

coil and are arranged to extend parallel or spirally (obliquely) along a groove top surface. Thus, the electromagnetic coil 3 has a two-layered structure having the one-side coil patterns 31 extending along the groove inner surface and the other-side coil patterns 32 extending along the groove top surface.

By using an electrically-conductive magnetic wire having a diameter of 1 - 150 μm as the magnetic sensitive member 2, the coil diameter can be held not larger than 200 μm .

[0032]

Using the magnetic wire 2 as the magnetic sensitive member is further advantageous in that, because the magnetic wire having superior magnetic sensitivity, an output voltage per winding of the electromagnetic coil is increased. Therefore, the number of windings can be reduced and the length of the MI device can be shortened.

[0033]

In addition, by employing a groove structure in which the groove 11 is formed in the electrode-wiring substrate 1, the sensor size can be further reduced as compared with the case of arranging the electromagnetic coil 3 on the electrode-wiring substrate 1. It is also possible to prevent the electromagnetic coil 3 from being externally touched, and to realize the MI device having improved mechanical stability.

[0034]

Moreover, in the MI device of this embodiment, the electrically-conductive magnetic wire is an amorphous wire.

By specifying the material of the magnetic wire to amorphous, the output voltage per winding of the electromagnetic coil can be increased because the amorphous has superior magnetic sensitivity. Therefore, the number of windings can be further reduced and the length of the MI device can be further shortened.

[0035]

In the MI device of this embodiment, the winding pitch per unit length of the electromagnetic coil 3 is not larger than 100 μm /winding.

By thus reducing the winding pitch per turn (unit length) of the electromagnetic coil 3 and increasing the number of windings per turn, the output voltage can be increased. From the practical point of view, the winding pitch is preferably not larger than 100 μm /winding. In other words, the length of the MI device can be shortened if the output voltage is the same.

[0036]

Further, in the MI device of this embodiment, the size of the electrode-wiring substrate 1 is set to a width ranging from 20 μm to 1 mm or below, a thickness ranging from 20 μm to 1 mm or below, and a length ranging from 200 μm to 4 mm or below.

Stated another way, since the width and height of

the electromagnetic coil 3 represented by a circle-equivalent coil diameter is 200 μm at maximum, it is possible to form the electrode-wiring substrate 1 and to realize a substantial reduction of size and thickness of the entire device.

[0037]

The relationship in arrangement among the MI devices in three X-, Y- and Z-directions in this embodiment will be described below with reference to Figs. 3 to 5.

As shown in Fig. 3, the base plate is constituted by a rectangular IC substrate 100 having four side wall surfaces which are orthogonal to each other between adjacent two. Side wall surfaces 1012, 1022 of the first sensor 101 and the second sensor 102 are disposed along adjacent side wall surfaces 1001, 1002 of the IC substrate, respectively, the first sensor 101 and the second sensor 102 being in the form of parallelepipeds having upper surfaces 1011, 1021 in each of which the elongate groove 11 and the coil 3 are formed to extend in the lengthwise direction. A side wall surface 1032 of the third sensor 103 is disposed along one 1003 of the two remaining side wall surfaces of the IC substrate 100, the third sensor 103 being in the form of a parallelepiped and having the elongate groove 11 and the coil 3 formed in the side wall surface 1032.

[0038]

Stated another way, as shown in Fig. 3, the first

sensor 101 is disposed such that its lengthwise direction lies in the X-direction, the second sensor 102 is disposed such that its lengthwise direction lies in the Y-direction, and the third sensor 103 is disposed such that its lengthwise
5 direction lies in the Z-direction.

[0039]

In each of the upper surfaces 1011, 1021 and the side wall surface 1032 of the first sensor 101, the second sensor 102 and the third sensor 103, the elongate groove 11 is
10 formed to extend in the lengthwise direction, the one coil members 31 constituting the coil 3 are formed parallel to one another at a constant pitch along the rectangular groove 11, and the other coil members 32 constituting the coil 3 are obliquely formed parallel to one another to
15 interconnect corresponding ends of two adjacent parallel coil patterns, which constitute the one coil members 31. Eventually, the coil 3 is formed in the spiral form as a whole.

[0040]

20 The insulator 4 is filled in a substantially rectangular space surrounded by the coil patterns 31, 32 which are formed along the rectangular groove 11. An amorphous wire, i.e., a magnetic wire serving as the magnetic sensitive member 2 to detect the magnetic field,
25 is inserted and held in a central portion of the insulator 4.

[0041]

Electrodes 51, 52 are disposed at opposite ends of each of the upper surfaces 1011, 1021 of the first sensor 101 and the second sensor 102 and are connected to opposite ends of the amorphous wire, i.e., the magnetic wire serving
5 as the magnetic sensitive member 2, and to the opposite ends of the coil 3. The electrodes 51, 52 are connected via leads 6 to electrodes (not shown) which are disposed in edge areas of the IC substrate 100 at positions near the adjacent side wall surfaces 1001, 1002 of the IC
10 substrate 100.

[0042]

Also, electrodes 51, 52 are disposed at vertical opposite ends of the side wall surfaces 1032 of the third sensor and are connected to the opposite ends of the
15 amorphous wire, i.e., the magnetic wire serving as the magnetic sensitive member 2, and to the opposite ends of the coil 3. More specifically, as shown in Fig. 4, the electrodes 51, 52 are formed to extend upward toward one of the vertical opposite ends of the side wall surfaces
20 1032, i.e., toward the upper end, to such an extent as finally extending over an upper surface 1031 of the third sensor. The electrodes 51, 52 formed on the upper surface 1031 are connected via leads 6 to electrodes (not shown) which are disposed in an edge area of the IC substrate 100 at a position
25 near the one 1003 of the two remaining side wall surfaces of the IC substrate 100. Note that, in Figs. 4 and 5, the coil patterns are shown at the pitch enlarged from the actual

one for the sake of clearly illustrating the coil layout.

[0043]

A process for forming the electrodes 51, 52 on the upper surface 1031 of the third sensor 103 will be described
5 below with reference to Fig. 6. A groove 1034 having a predetermined width is formed at each of lengthwise opposite ends of the electrode-wiring substrate 1 constituting the third sensor 103 (Fig. 6 shows only one end as a representative). On the upper surface of the third
10 sensor 103 as viewed in Fig. 6, the electrodes 51, 52 are formed to be connected to the opposite ends of the amorphous wire, i.e., the magnetic wire serving as the magnetic sensitive member 2, and to the opposite ends of the coil 3. At that time, as shown in Fig. 5, the electrodes 51,
15 52 are formed to extend in the lengthwise direction until reaching the right end of the third sensor 103, thus forming wide electrodes 51, 52 to extend on an inner wall surface of the groove 1034, i.e., on an end surface of the third sensor 103, in the direction of groove depth. By cutting
20 the substrate at the groove 1034, each sensor piece can be obtained.

[0044]

In the thus-constructed three-dimensional magnetic bearing sensor according to the embodiment, the first
25 sensor 101 disposed to lie in the X-direction of the IC substrate 100, the second sensor 102 disposed to lie in the Y-direction of the IC substrate 100, and the third sensor

103 disposed to lie in the Z-direction of the IC substrate
100 are each constituted by the magneto-impedance sensor
device with the electromagnetic coil, which comprises the
electromagnetic coil 3 having the spiral shape and being
5 made up of the one coil patterns 31 formed in the elongate
groove 11 extending in the electrode-wiring substrate 1
in the certain direction and the other coil patterns 32
connecting the corresponding upper ends of the one coils
31 to each other, and the magnetic sensitive member 2 which
10 is inserted in the insulator 4 filled in the elongate groove
11 of the electrode-wiring substrate 1 and to which is
applied a high-frequency wave or a pulse current. Each
of the magneto-impedance sensor devices outputs a voltage
generated in the electromagnetic coil depending on the
15 intensity of an external magnetic field when the
high-frequency wave or the pulse current is applied,
thereby detecting X-, Y- and Z-direction components of the
external magnetic field.

[0045]

20 The three-dimensional magnetic bearing sensor
according to the embodiment, which operates as described
above, has the following advantage because of the specific
features. More specifically, the first to third sensors
101 - 103 disposed to lie in the X-, Y- and Z-directions
25 of the IC substrate 100 are constituted by the
magneto-impedance sensor devices with the electromagnetic
coils, each of which comprises the electromagnetic coil

3 having a spiral shape and being made up of the one coil patterns 31 formed in the elongate groove 11 extending in the electrode-wiring substrate 1 in the certain direction and the other coil patterns 32 connecting the corresponding upper ends of the one coil patterns 31 to each other, and the magnetic sensitive member 2 which is inserted in the insulator 4 filled in the elongate groove 11 of the electrode-wiring substrate 1 and to which is applied a high-frequency wave or a pulse current. The magneto-impedance sensor devices have small sizes of ($0.5 \times 1.0 \times 0.5$, $0.5 \times 1.0 \times 0.5$, $0.6 \times 1.2 \times 1.0$), respectively. Therefore, reduction of the sensor size can be realized.

[0046]

Also, the three-dimensional magnetic bearing sensor according to the embodiment has the following advantage because of the specific features. More specifically, each of the first to third sensors 101 - 103 disposed to lie in the X-, Y- and Z-directions of the IC substrate 100 outputs a voltage generated in the electromagnetic coil depending on the intensity of an external magnetic field when the high-frequency wave or the pulse current is applied, thereby detecting X-, Y- and Z-direction components of the external magnetic field. Therefore, the bearing can be detected with sufficient accuracy regardless of the attitude of the magnetic bearing sensor.

[0047]

Further, the three-dimensional magnetic bearing

sensor according to the embodiment has the following advantage because of the specific features. More specifically, the base plate is constituted by the rectangular IC substrate 100 having four side wall surfaces which are orthogonal to each other between adjacent two. The side wall surfaces 1012, 1022 of the first sensor 101 and the second sensor 102 are disposed along the adjacent side wall surfaces 1001, 1002 of the IC substrate, respectively, the first sensor 101 and the second sensor 102 having the upper surfaces 1011, 1021 in each of which the elongate groove 11 is formed in the lengthwise direction. The side wall surface 1032 of the third sensor 103 is disposed along the one 1003 of the two remaining side wall surfaces of the IC substrate 100, the third sensor 103 having the elongate groove 11 formed in the side wall surface 1032. Therefore, the sensor structure is simple and the same sensor can be used as each of the first sensor 101 and the second sensor 102.

[0048]

In addition, the thus-constructed three-dimensional magnetic bearing sensor according to the embodiment has the following advantage because of the specific features. More specifically, the electrodes 51, 52 formed at the opposite ends of each of the upper surfaces of the first sensor 101 and the second sensor 102 are connected via the leads 6 to the electrodes which are disposed in the edge areas of the IC substrate 100 at positions near the adjacent

side wall surfaces 1001, 1002 of the IC substrate 100. The electrodes 51, 52 disposed on the upper surface of the third sensor 103 are connected via the leads 6 to the electrodes which are disposed in the edge area of the IC substrate 100 at a position near the one 1003 of the two remaining side wall surfaces of the IC substrate 100. Therefore, the sensors and the electrodes of the IC substrate can be easily connected to each other.

[0049]

10 (Examples)

Examples of the present invention will be described below with reference to the drawings.

[0050]

(First Example)

15 A magneto-impedance sensor device with an electromagnetic coil used in a three-dimensional magnetic bearing sensor according to this first example will be described below with reference to Figs. 1 and 2.

The substrate 1 has dimensions of 0.5-mm width, 0.5-mm height, and 2-mm length. The magnetic sensitive member 2 is an amorphous wire 2 made of a CoFeSiB-based alloy and having a diameter of 20 μm . The groove 11 formed in the substrate has a depth of 50 μm , a width of 70 μm , and a length of 2 mm. The electromagnetic coil 3 has the two-layered structure having the one-side coil patterns 31 formed on a groove inner surface 111 and the other-side coil patterns 32 formed on a groove top surface 112 (i.e.,

on an upper surface 41 of the resin 4 as the insulator).

[0051]

As shown in Figs. 6, 7 and 8, the one-side coil patterns 31 are formed on the groove inner surface 111 through the steps of forming a conductive metallic thin film constituting the coil by vapor deposition all over the groove inner surface 111 of the groove 11 formed in the electrode-wiring substrate 1 to extend in its lengthwise direction and over an area of the upper surface of the electrode-wiring substrate 1 near the groove 11, and partly removing the formed conductive metallic thin film by selective etching only in areas corresponding to gaps between the coil patterns so that the metallic thin film is left in the spiral form.

15 [0052]

More specifically, vertical coil members 311 are formed to vertically extend on groove side surfaces 113 of the groove 11, and horizontal coil members 312 are formed on a groove bottom surface 110 of the groove 11 to extend obliquely with respect to the widthwise direction such that the formed horizontal coil members 312 are continuously connected to the adjacent vertical coil members.

[0053]

The other-side coil patterns 32 on the groove top surface 112 (i.e., on the upper surface 41 of the resin 4) are formed as follows. A conductive metallic thin film constituting the coil is formed by vapor deposition on the

lower surface 112 of the upper substrate 12 in a portion opposed to the groove 11 formed in the electrode-wiring substrate 1 to extend in its lengthwise direction over a larger region than the groove 11 in the widthwise direction.

5 Then, the formed conductive metallic thin film is partly removed by selective etching to form gaps between the coil patterns at a certain pitch so that the metallic thin film is left at the certain pitch while extending over a length larger than the widthwise length of the groove 11 in the
10 strip form lying in the widthwise direction.

[0054]

The winding inner diameter of the electromagnetic coil 3 is 66 μm in terms of the circle-equivalent inner diameter (i.e., the diameter of a circle having the same
15 cross-sectional area as that of a groove defined by a height and a width). The winding pitch of the electromagnetic coil 3 per turn (unit length) is 50 μm .

[0055]

The insulating resin 4 is interposed between the
20 amorphous wire 2 and the electromagnetic coil 3 to ensure insulation between the electrically-conductive magnetic amorphous wire and the electromagnetic coil 3. Total four electrodes 5 are formed on the upper surface of the base plate to serve as two terminals 51 of the electromagnetic
25 coil and two terminals 52 of the magnetic sensitive member. Opposite ends of the amorphous wire 2 and opposite ends of the electromagnetic coil 3 are connected to the

corresponding electrodes 5. The MI device 10 according to the embodiment of the present invention is constructed as described above. The size of the MI device is the same as that of the electrode-wiring substrate.

5 [0056]

Characteristics of the MI device 10 were evaluated by using an MI sensor shown in Fig. 10.

An MI sensor electronic circuit used for the evaluation comprises a signal generator 6, three MI devices 10, and a signal processing unit 7. The signal generator 6 generates a pulse signal having the intensity of 170 mA at signal intervals of 1 μ sec corresponding to 200 MHz. The electronic circuit applies the pulse signal to the amorphous wire 2. The pulse signal is inputted to the amorphous wire 2, and a voltage is induced in the electromagnetic coil 3 in proportion to an external magnetic field during a time in which the pulse signal is inputted.

[0057]

20 The signal processing circuit 7 takes out the voltage induced in the electromagnetic coil 3 through synchronous detection 71 that is turned on/off in sync with the pulse signal from the signal generator 6, and the taken-out voltage is amplified by an amplifier 72 to a predetermined voltage.

25 [0058]

Meanwhile, dimensions of a known bobbin-type MI

device 9 shown as a comparative example in Fig. 12 are as follows. A substrate 91 to which is fixed an amorphous wire has dimensions of 0.7-mm width, 0.5-mm height, and 3.5-mm length. A magnetic sensitive member is an amorphous wire 92 made of a CoFeSiB-based alloy and having a diameter of 30 μm . An insulating winding frame 94 is interposed between the amorphous wire 92 and the electromagnetic coil 93 to ensure insulation between the electrically-conductive magnetic amorphous wire and the electromagnetic coil.

[0059]

A resin-molded core portion of the winding frame 94 has a width of 1 mm, a height of 1 mm and a length of 3 mm. On that condition, the electromagnetic coil 93 has an inner diameter of 1.5 mm. Total four electrodes 95 are disposed on the winding frame 94 to serve as two terminals of the electromagnetic coil and two terminals of the magnetic sensitive member. Opposite ends of the amorphous wire 92 and opposite ends of the electromagnetic coil 93 are connected to the corresponding electrodes 95. The known MI device 9 is constructed as described above. The known MI device 9 has dimensions of 3-mm width, 2-mm height, and 4-mm length. Thus, the known MI device has a comparatively large size and cannot be applied to a sensor having a limited installation space.

[0060]

In contrast, the three-dimensional magnetic bearing

sensor according to this first example is so very small and thin that it can be applied to a super-small magnetic sensor for microelectronic equipment, such as a sensor for a cellular phone and a sensor for a wristwatch.

5 [0061]

This first example has the following advantage because of the specific features. More specifically, the electromagnetic coil is formed through the steps of forming a conductive metallic thin film constituting the coil by
10 vapor deposition on the groove inner surface 111 of the groove 11 formed in the electrode-wiring substrate 1 to extend in its lengthwise direction and on the lower surface 112 of the upper substrate 12, and partly removing the formed conductive metallic thin film by selective etching only
15 in areas corresponding to gaps between the coil patterns so that the metallic thin film is left in the spiral form. Therefore, a small-sized and thin MI device can be manufactured with high density.

[0062]

20 As a result of a practical test of the MI device 10 according to this first example, it was confirmed that superior linearity was obtained in a magnetic field range of ± 10 G in spite of the device size being reduced to a very large extent as shown in Figs. 7 to 9, i.e., about
25 $1/50$ (exactly $1/48$), in comparison with the MI sensor using the known MI device. More specifically, as shown in Fig. 9, the width of the coil pattern 311 and the coil pattern

312 in the lengthwise direction of the groove 11 is set to any of 50 μm , 10 μm , 25 μm , etc., and the width of the gap between the coil patterns is set correspondingly to any of 25 μm , 5 μm , 25 μm , etc.

5

[0063]

For comparison, Fig. 11 shows results of comparing a linear range between the comparative example shown in Fig. 12, i.e., the known bobbin-type sensor (wire length of 2.5 mm, coil length of 2 mm, and 40 turns) and the sensor of the first example (wire diameter of 20 μm , wire length of 1.5 mm, coil length of 1 mm, and 18 turns). In Fig. 11, the horizontal axis represents an external magnetic field, and the vertical axis represents an output voltage.

10

[0064]

15

As seen from Fig. 11, the known bobbin-type sensor and the sensor of this first example have linear ranges substantially equal to each other, i.e., about ± 3 G, and the output voltage of the sensor of this first example is 80% or more of that of the known bobbin-type sensor. Thus, in the sensor of this first example, a lowering of the output voltage is restrained in spite of reduction in size and thickness. On the other hand, because of a large difference in the number of windings, the voltage per turn produced from the sensor of this first example is 53 mV/turn as compared with 28 mV/turn produced from the bobbin-typed device, i.e., about times. Therefore, the sensor of this first example is more adaptable for size reduction.

20

25

[0065]

(Second Example)

A three-dimensional magnetic bearing sensor of this second example is constituted by using three
5 magneto-impedance sensor devices with the electromagnetic coils according to the first example, and it will be described below with reference to Figs. 3 to 6.

[0066]

In this second example, the Z-direction sensor 103
10 of the MI sensor chip is manufactured to be adapted for joining to the IC substrate 100.

The Z-direction chip of the MI sensor is manufactured by employing a photolithographic process (semiconductor technique). At the same time as forming the groove 11 by
15 etching or the like in the step of manufacturing the Z-direction chip, joint pads are also formed on the side surface 1032 of the chip 103 in which the groove 11 is formed.

[0067]

The Z-direction chip 103 is cut into a desired size.
20 The cut Z-direction chip 103 is fixed in place in a vertically standing state. More specifically, the joint pads on the side surface of the Z-direction chip 103 are turned to position vertically, and the joint pads are joined to the side surface 1003 of the IC substrate 100 by wire bonding,
25 for example.

[0068]

In Fig. 3, (1) represents the width of the third sensor

103, (2) represents the length of the third sensor 103 in its lengthwise direction, and (3) represents the height of the third sensor 103.

Also, in Fig. 3, (5) represents the width of the first sensor 101, (4) represents the length of the first sensor 101 in its lengthwise direction, and (6) represents the height of the first sensor 101.

Further, in Fig. 3, (7) represents the width of the second sensor 102, (8) represents the length of the second sensor 102 in its lengthwise direction, and (9) represents the height of the second sensor 102.

[0069]

Design values, ranges of values actually measured on the sensor, and desired values (dimension allowable ranges) of the various dimensions (1) to (9) in Fig. 3 are listed in Table 1 in units of mm.

[Table 1]

	design value	range	desired value	unit
(1)	0.6	0.2~1.2	0.2~1.2	mm
(2)	1.2	0.3~2.0	0.3~2.0	mm
(3)	1.0	0.3~2.5	0.3~2.5	mm
(4)	1.0	0.2~2.5	0.2~2.5	mm
(5)	0.5	0.2~2.0	0.2~2.0	mm
(6)	0.4	0.2~2.5	0.2~2.5	mm
(7)	0.5	0.2~2.0	0.2~2.0	mm
(8)	1.0	0.2~2.5	0.2~2.5	mm
(9)	0.4	0.2~2.5	0.2~2.5	mm

[0070]

The sensor dimensions will be described in more detail

below with reference to Fig. 4 and 5.

In Fig. 4, (1) represents the width of the third sensor 103, (2) represents the length of the third sensor 103 in its lengthwise direction, and (3) represents the height of the third sensor 103.

[0071]

In Fig. 4, (4) represents the width of the one-side coil pattern 31 in the third sensor 103, which is formed on the groove inner surface 111 of the groove 11 formed in the electrode-wiring substrate 1 to extend in its lengthwise direction, and (5) represents the pitch between the adjacent one-side coil pattern 31.

[0072]

Design values, ranges of values actually measured on the sensor, and desired values (dimension allowable ranges) of the various dimensions (1) to (5) in Fig. 4 are listed in Table 2 in units of mm. Note that (4) in Fig. 4 represents the width of each coil pattern and (5) represents the pitch of the coil patterns.

[Table 2]

	design value	range	desired value	unit
(1)	0.6	0.2~1.2	0.2~1.2	mm
(2)	1.2	0.3~2.0	0.3~2.0	mm
(3)	1.0	0.3~2.5	0.3~2.5	mm
(4)	0.025	0.005~0.100	0.005~0.100	mm
(5)	0.025	0.005~0.100	0.005~0.100	mm
(6)	20	3~50	3~50	tern

[0073]

In Fig. 5, (1) represents the height of the first and second sensors 101, 102, (2) represents the width of the first and second sensors 101, 102, and (3) represents the length of the first and second sensors 101, 102 in the lengthwise direction thereof.

[0074]

In Fig. 5, (4) represents the width of the one-side coil pattern 31 in each of the first and second sensors 101, 102, which is formed on the groove inner surface 111 of the groove 11 formed in the electrode-wiring substrate 1 in its lengthwise direction, and (5) represents the pitch between the adjacent one-side coil pattern 31.

[0075]

Design values, ranges of values actually measured on the sensor, and desired values (dimension allowable ranges) of the various dimensions (1) to (5) in Fig. 5 are listed in Table 2 in units of mm. Note that (4) in Fig. 5 represents the width of each coil pattern and (5) represents the pitch of the coil patterns.

[Table 3]

	design value	range	desired value	unit
(1)	0.5	0.2~1.0	0.2~1.0	mm
(2)	0.5	0.2~2.0	0.2~2.0	mm
(3)	1.5	0.3~2.5	0.3~2.5	mm
(4)	0.025	0.005~0.100	0.005~0.100	mm
(5)	0.025	0.005~0.100	0.005~0.100	mm
(6)	20	3~50	3~50	tern

[0076]

In Fig. 6, (1) represents the width of the groove 1034 formed in the process of manufacturing the third sensor 103, (2) represents the depth of the groove 1034, (3) represents the width of the wide electrodes 51, 52 formed to extend on the wall surface of the groove 1034, and (4) represents the number of turns of the coil 2 formed in the third sensor 103 along the groove 11. The illustrated substrate is divided into many sensor devices by cutting it at the groove 1034 in a subsequent step.

[0077]

Design values, ranges of values actually measured on the sensor, and desired values (dimension allowable ranges) of the various dimensions (1) to (3) in Fig. 6 and the number of coil turns are listed in Table 4 in units of mm.

[Table 4]

	design value	range	desired value	unit
(1)	0.15	0.05~1.0	0.2~1.2	mm
(2)	0.15	0.03~2.0	0.3~2.0	mm
(3)	0.1	0.03~0.3	0.3~2.5	mm
(4)	20	3~50	3~50	turn

[0078]

The three-dimensional magnetic bearing sensor of this second example detects respective magnetic field components in the X-, Y- and Z-directions by the three magneto-impedance sensor devices with the electromagnetic coils, which are disposed in the predetermined positions with respect to the IC substrate, and issues X-, Y- and

Z-direction outputs having different phases, as shown in Figs. 13 to 15, to the signal processing circuit 7 shown in Fig. 10, which is integrally formed on the IC substrate 100.

5 [0079]

The three-dimensional magnetic bearing sensor of this second example, which is constructed and operated as described above, has an advantage of enabling simultaneous magnetic field sensing in the X-, Y- and Z-directions, which
10 has been difficult to realize with the known techniques, to be performed by using the three magneto-impedance sensor devices with the electromagnetic coils according to the first example. It is therefore possible to realize the simultaneous magnetic field sensing with a smaller sensor,
15 and to easily perform various kinds of micro-sensing of magnetic field distribution, magnetizing direction, etc.

[0080]

Another advantage of the three-dimensional magnetic bearing sensor according to the second example is as follows.
20 Since one of the sensors manufactured in accordance with a two-dimensional process is oriented to stand in a state turned a right angle from the attitude of the other sensors and is joined to one side surface of the IC substrate 100 by bonding, an expensive three-dimensional process is not
25 required and the cost can be cut.

[0081]

The foregoing embodiment is described by way of an

illustrative example only, and the present invention is not limited to the described one and can be modified or combined with suitable additional matters without departing from the technical concept of the present invention which is recognized by those skilled in the art from the claims, the detailed description of the invention, and the drawings.

[0082]

While the foregoing embodiment and examples are described, by way of example, in connection with the case where the third sensor is manufactured in different shape and dimensions from those of the first and second sensors, the present invention is not limited to that case. As an alternative embodiment and example, the first to third sensors may be manufactured in the same shape and dimensions, and only a manner of joining the third sensor to the IC substrate may be changed.

[0083]

While the foregoing embodiment and examples are described, by way of example, in connection with the case where the first and second sensors 101, 102 are disposed along the adjacent side wall surfaces of the substrate 100 which are orthogonal to each other and the third sensor 103 is disposed along one of the two remaining side wall surfaces of the substrate 100, the present invention is not limited to that case. Alternative embodiments may be constituted in other layouts as shown in Fig. 16. In one

layout, the first and second sensors 101, 102 are disposed along the adjacent side wall surfaces of the substrate 100 which are orthogonal to each other, and the third sensor 103 is disposed along the side wall surface of the substrate 100 along which is disposed the first sensor (X) 101. In another layout, the third sensor 103 is disposed along the side wall surface of the substrate 100 along which is disposed the second sensor (Y) 102. In still another layout, the first to third sensors 101 - 103 are disposed along one side wall surface of the substrate 100. In still another layout, the first to third sensors 101 - 103 are disposed on the upper surface (or the lower surface) of the substrate 100.

[Brief Description of the Drawings]

15 [Fig. 1]

Fig. 1 is a front view showing an MI device according to an embodiment and a first example of the present invention.

[Fig. 2]

20 Fig. 2 is a cross-sectional view taken along line A-A' in Fig. 1, showing the MI device according to the embodiment and the first example.

[Fig. 3]

25 Fig. 3 is a perspective view showing an overall construction of the embodiment and the example of the present invention.

[Fig. 4]

Fig. 4 is a perspective view showing a third sensor according to the embodiment and the example of the present invention.

[Fig. 5]

5 Fig. 5 is a perspective view showing a first sensor and a second sensor according to the embodiment and the example of the present invention.

[Fig. 6]

10 Fig. 6 is a partial perspective view for explaining formation of electrodes of the third sensor according to the embodiment and the example of the present invention.

[Fig. 7]

15 Fig. 7 is a partial perspective view showing arrangement of a coil in a groove according to the embodiment and the first example.

[Fig. 8]

Fig. 8 is a partial plan view showing arrangement of the coil in the groove according to the embodiment and the first example.

20 [Fig. 9]

Fig. 9 is a partial plan view showing arrangement of the coil in the groove according to the embodiment and the first example.

[Fig. 10]

25 Fig. 10 is a circuit block diagram showing an electronic circuit for the MI sensor according to the embodiment and the first example.

[Fig. 11]

Fig. 11 is a graph showing the relationship between an external magnetic field and an output voltage in the sensor according to the example and a known bobbin-type
5 sensor.

[Fig. 12]

Fig. 12 is a front view showing a known bobbin-type MI device as a comparative example.

[Fig. 13]

10 Fig. 13 is a graph showing X- and Y-axis outputs detected by the sensor according to the example.

[Fig. 14]

Fig. 14 is a graph showing X- and Z-axis outputs detected by the sensor according to the example.

15 [Fig. 15]

Fig. 15 is a graph showing Y- and Z-axis outputs detected by the sensor according to the example.

[Fig. 16]

20 Fig. 16 is a plan view showing other examples of layout of the first to third sensors with respect to a substrate according to the present invention.

[Reference Numerals]

1: electrode-wiring substrate
11: elongate groove
25 100: IC substrate
101: first sensor
102: second sensor

103: third sensor

2: magnetic sensitive member

3: electromagnetic coil

31: one coil pattern

32: other coil pattern

4: insulator

5

[Name of Document] ABSTRACT

[Abstract]

[Object] To facilitate manufacturing and assembly steps,
and to realize size reduction.

5 [Solving Means] A three-dimensional magnetic bearing
sensor is constituted by using a magneto-impedance sensor
device with an electromagnetic coil, which comprises an
electromagnetic coil 3 having a spiral shape and being made
up of one coil members 31 formed in an elongate groove 11
10 extending in an electrode-wiring substrate 1 in a certain
direction and other coil members 32 connecting
corresponding upper ends of the one coil members 31 to each
other, and a magnetic sensitive member 2 which is inserted
in an insulator 4 filled in the elongate groove 11 of the
15 electrode-wiring substrate 1 and to which is applied a
high-frequency wave or a pulse current, thereby outputting
a voltage generated in the electromagnetic coil 3 depending
on the intensity of an external magnetic field when the
high-frequency wave or the pulse current is applied. The
20 three-dimensional magnetic bearing sensor includes a first
sensor 101 disposed to lie in an X-direction of an IC
substrate 100 which serves as a base plate, a second sensor
102 disposed to lie in a Y-direction of the IC substrate,
and a third sensor 103 disposed to lie in a Z-direction
25 of the IC substrate.

[Selected Figure] Fig. 3



FIG. 1

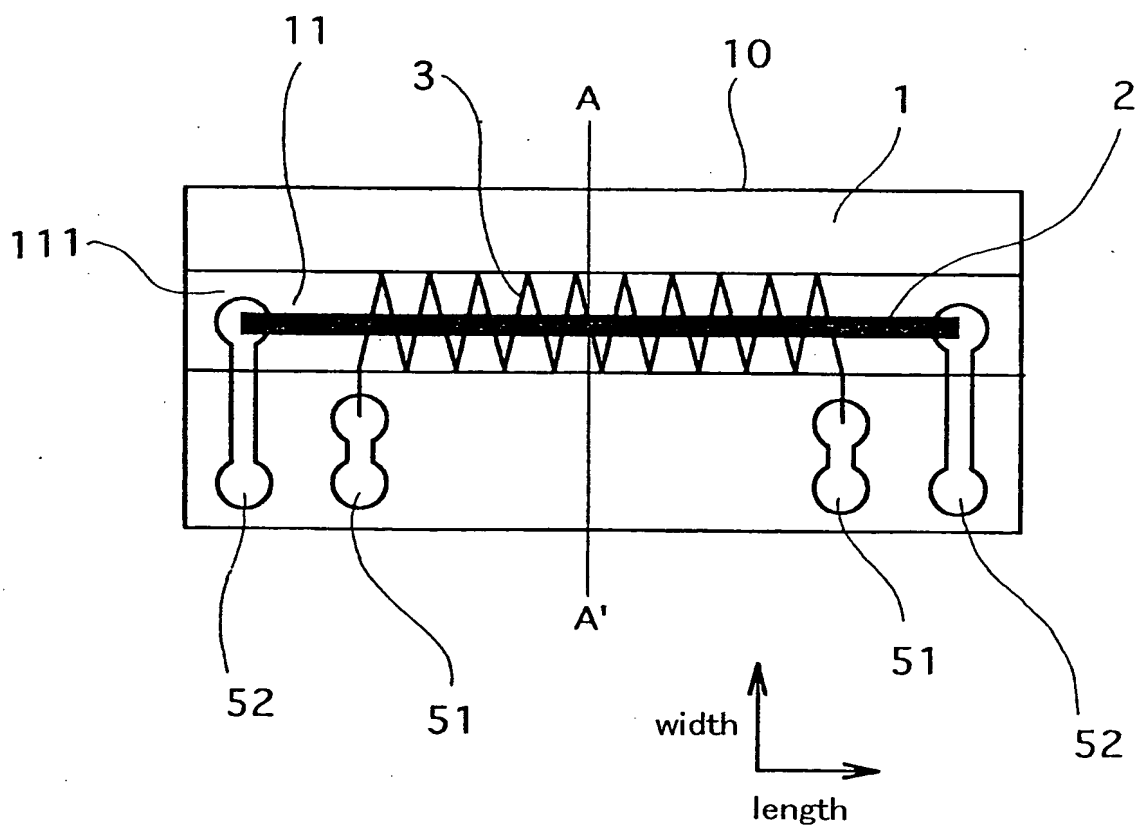


FIG. 2

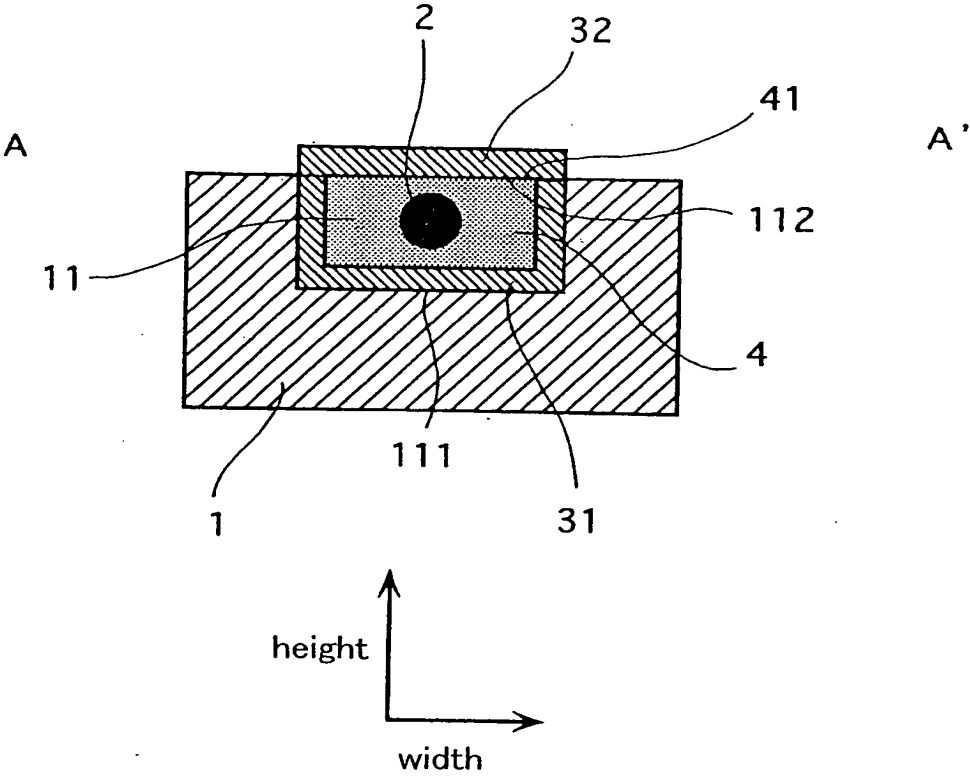


FIG. 3

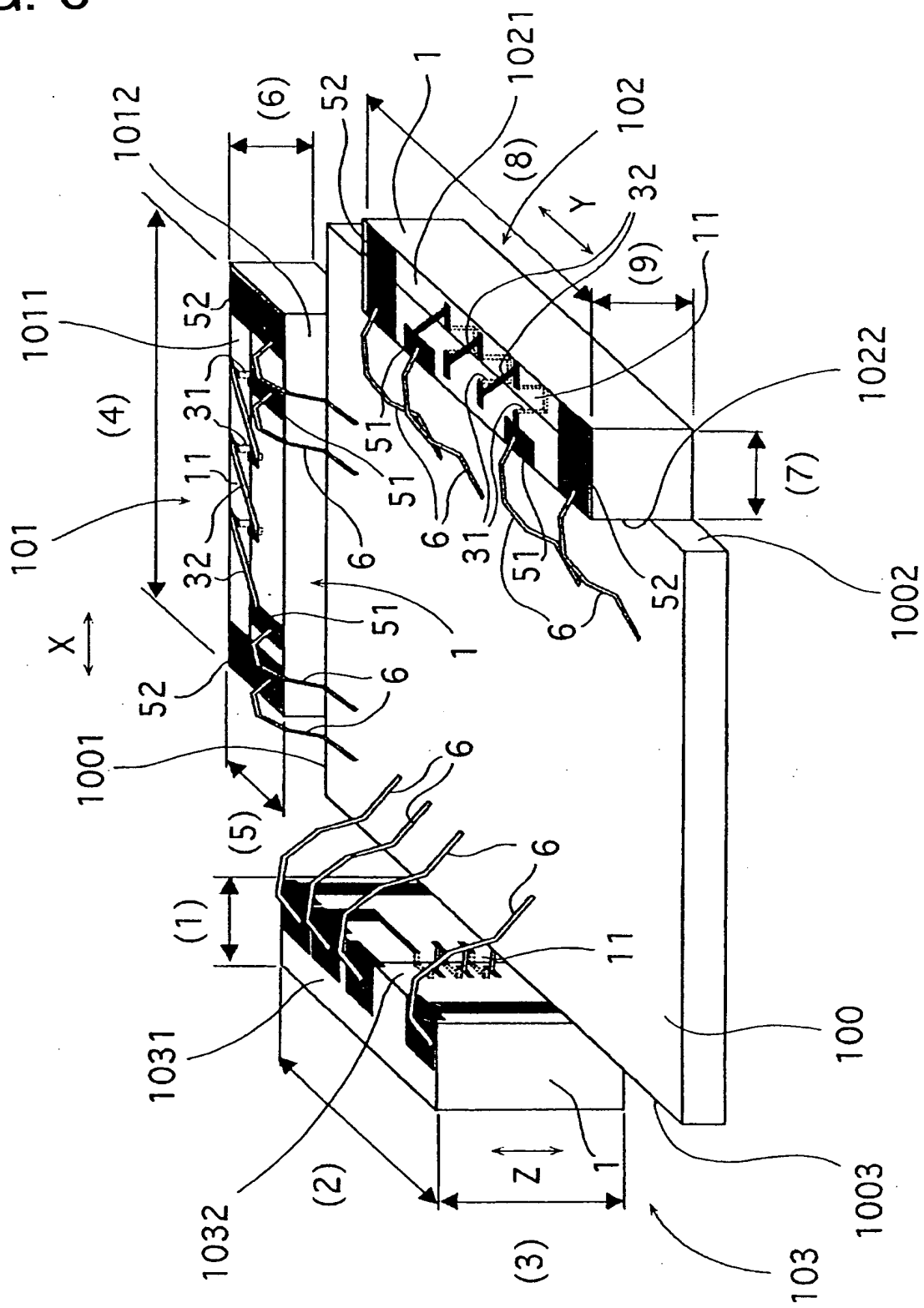


FIG. 4

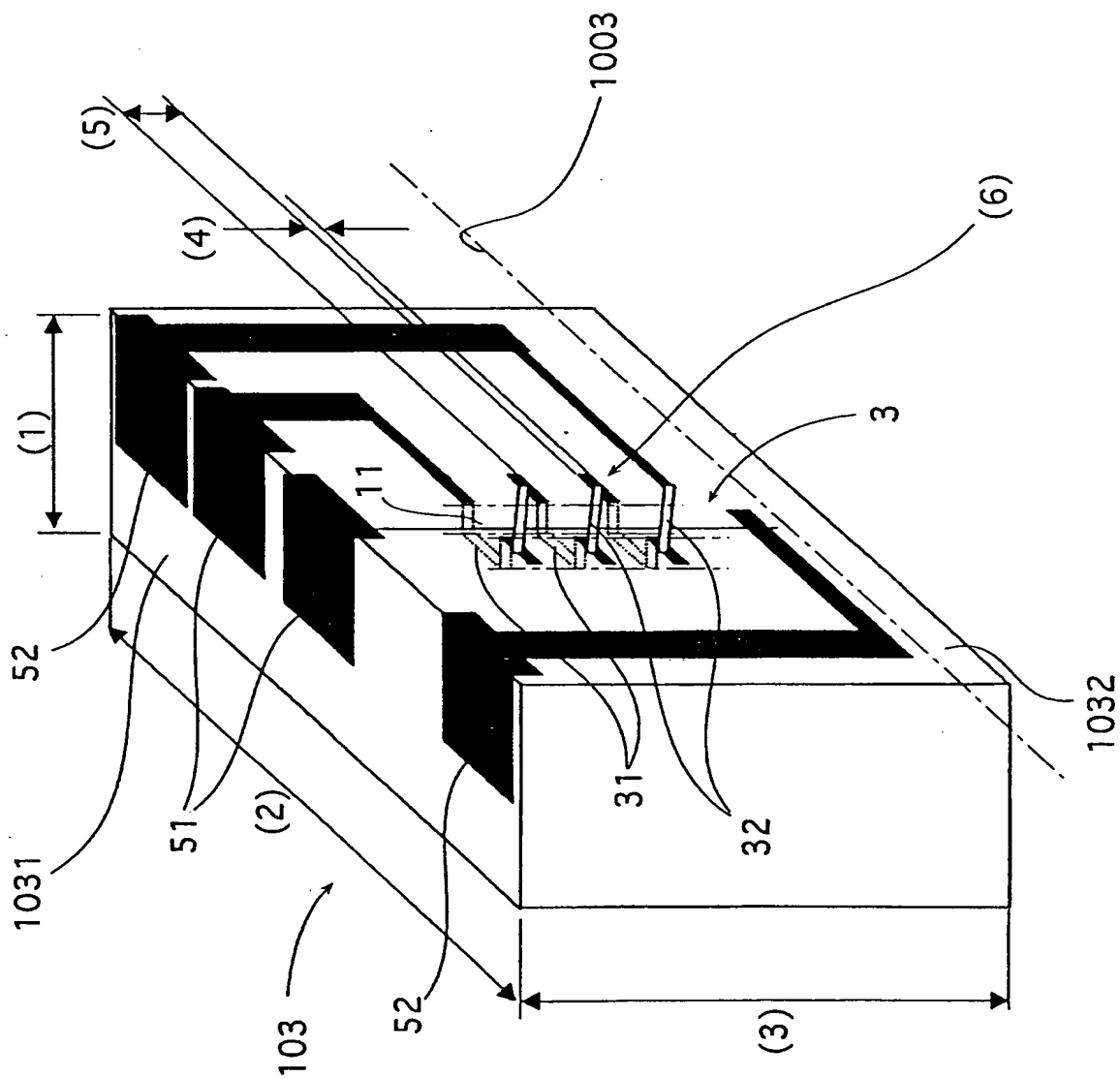


FIG. 5

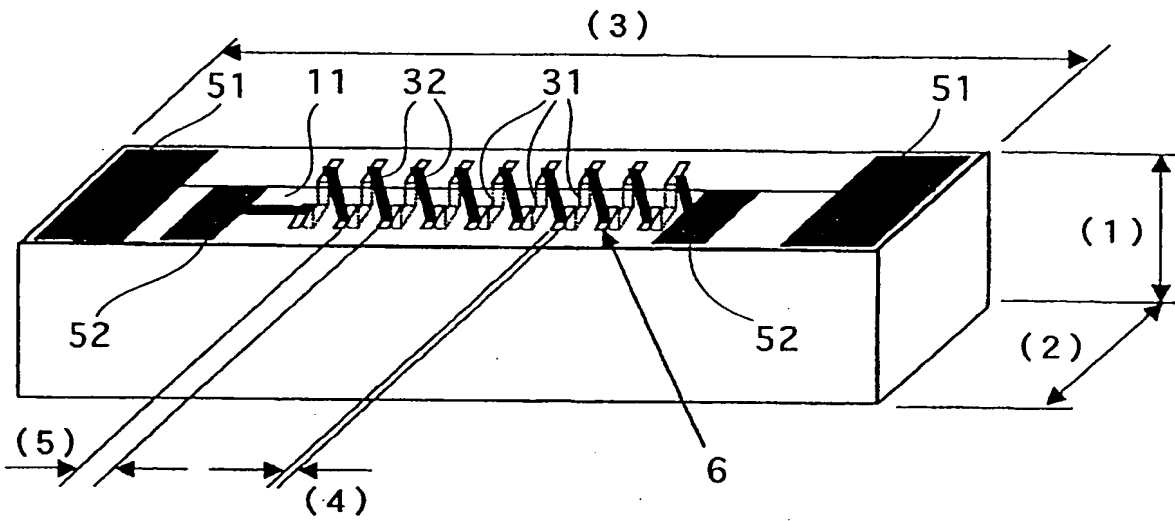


FIG. 6

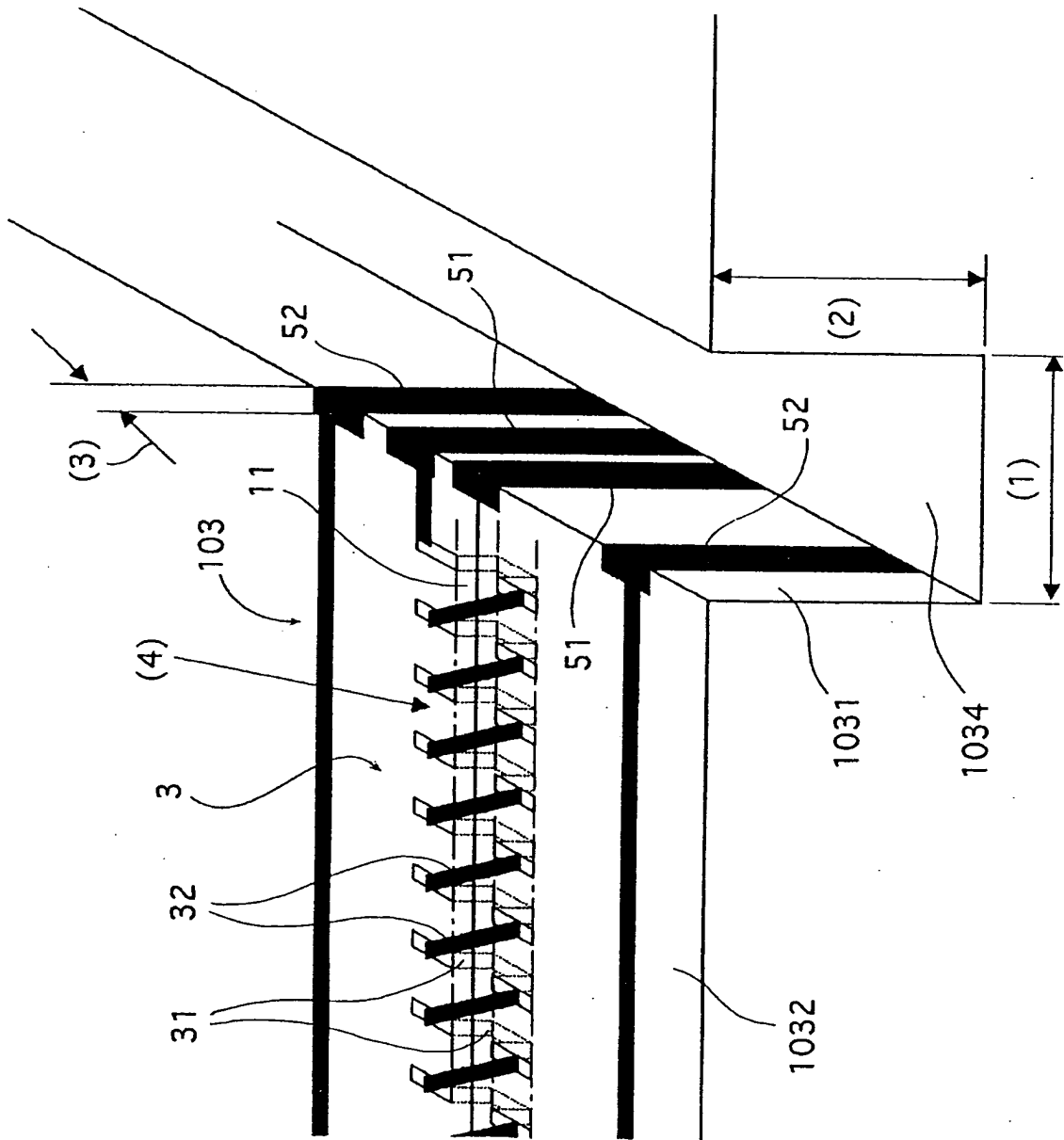


FIG. 7

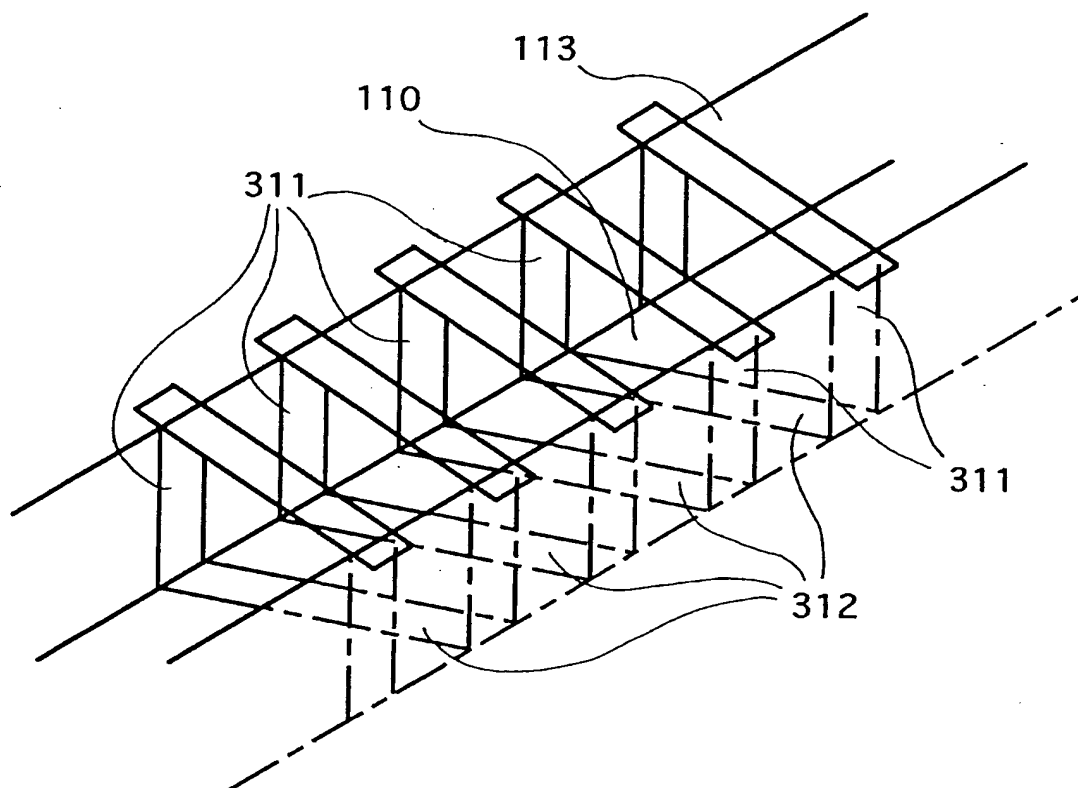


FIG. 8

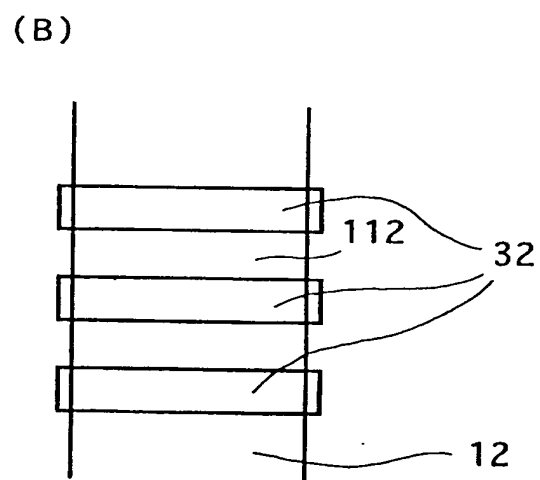
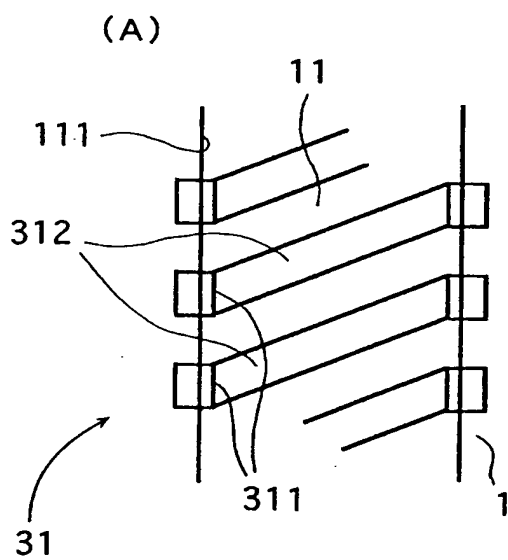


FIG. 9

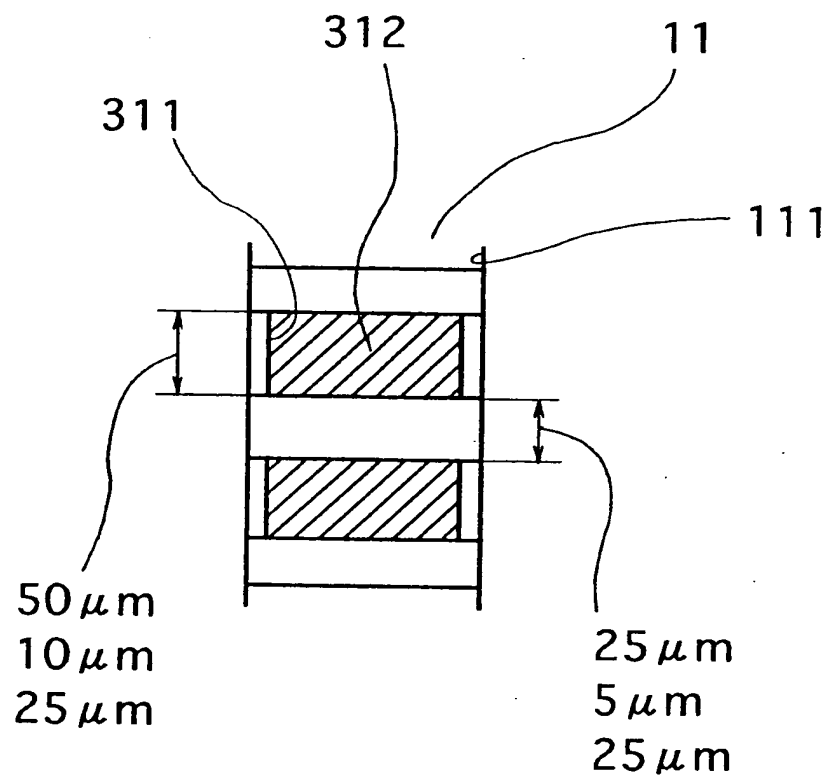


FIG. 10

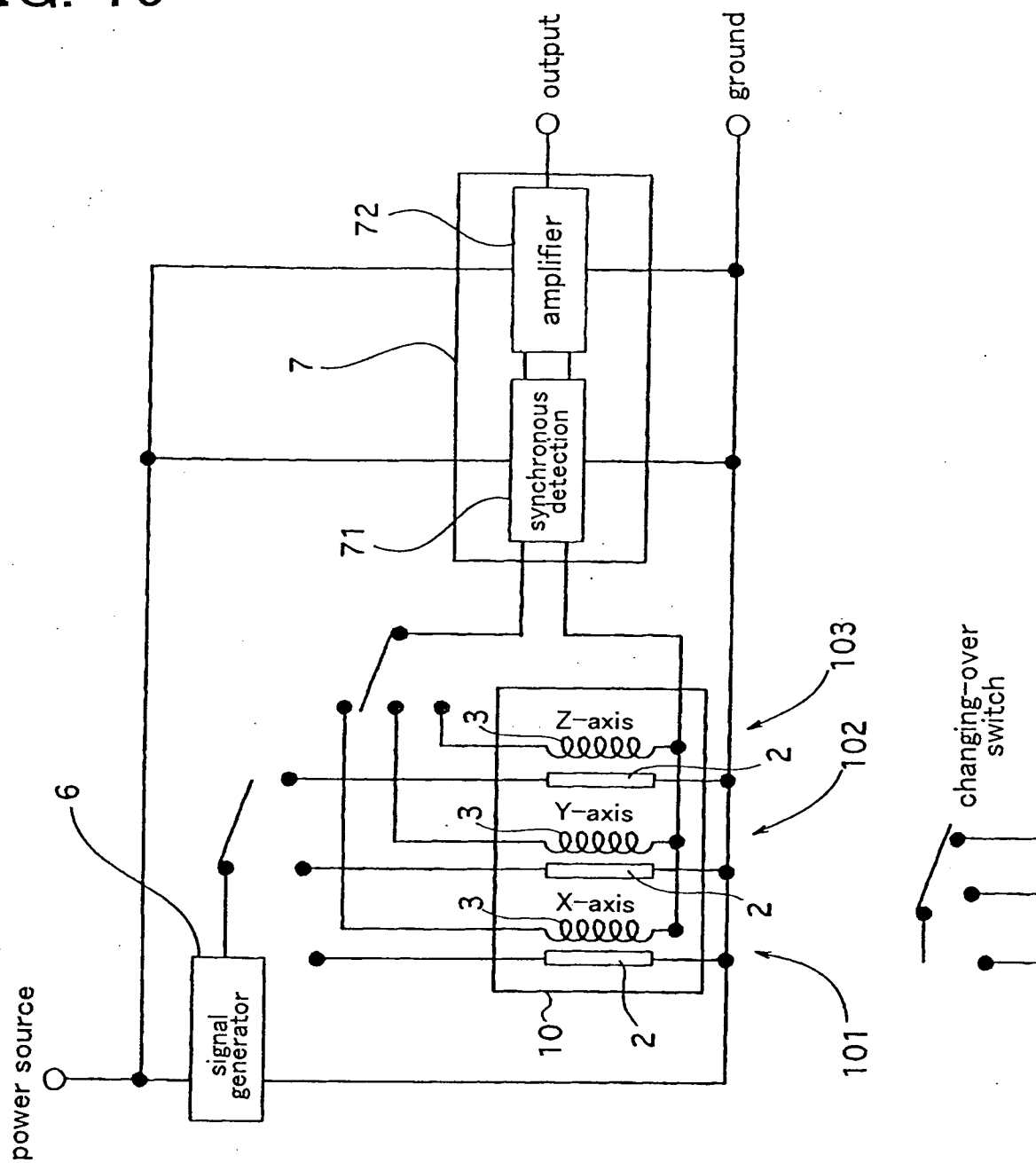


FIG. 11

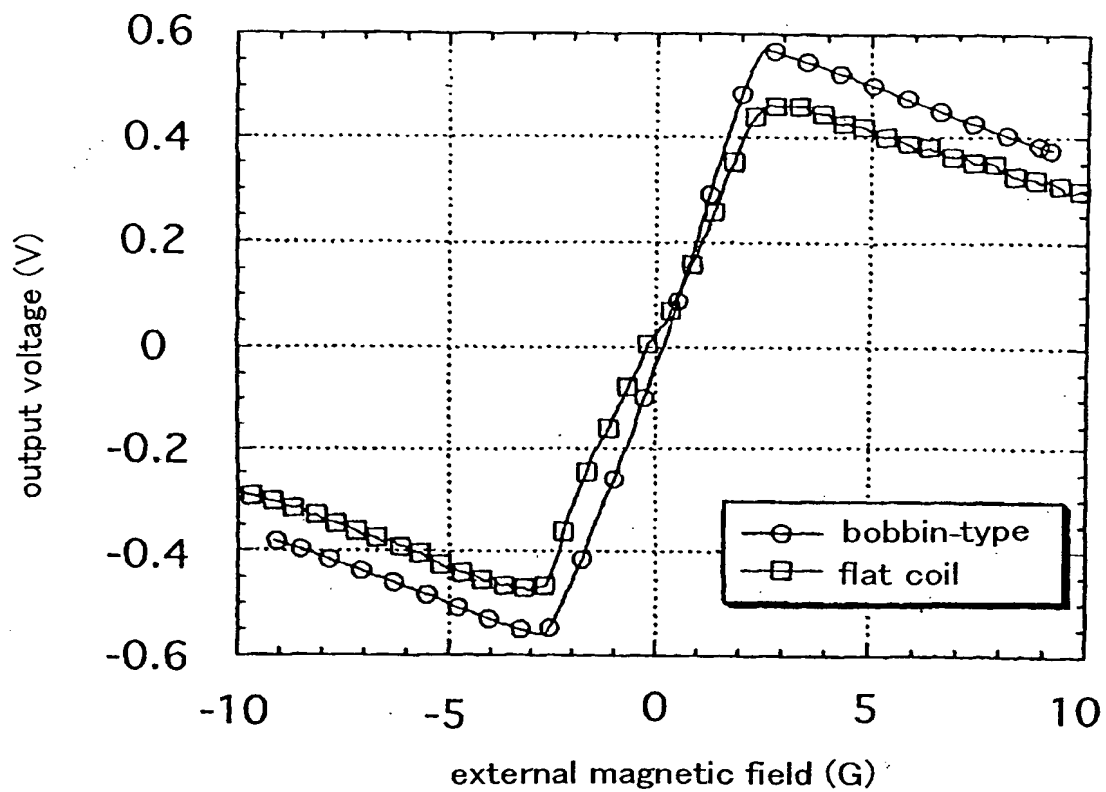


FIG. 12

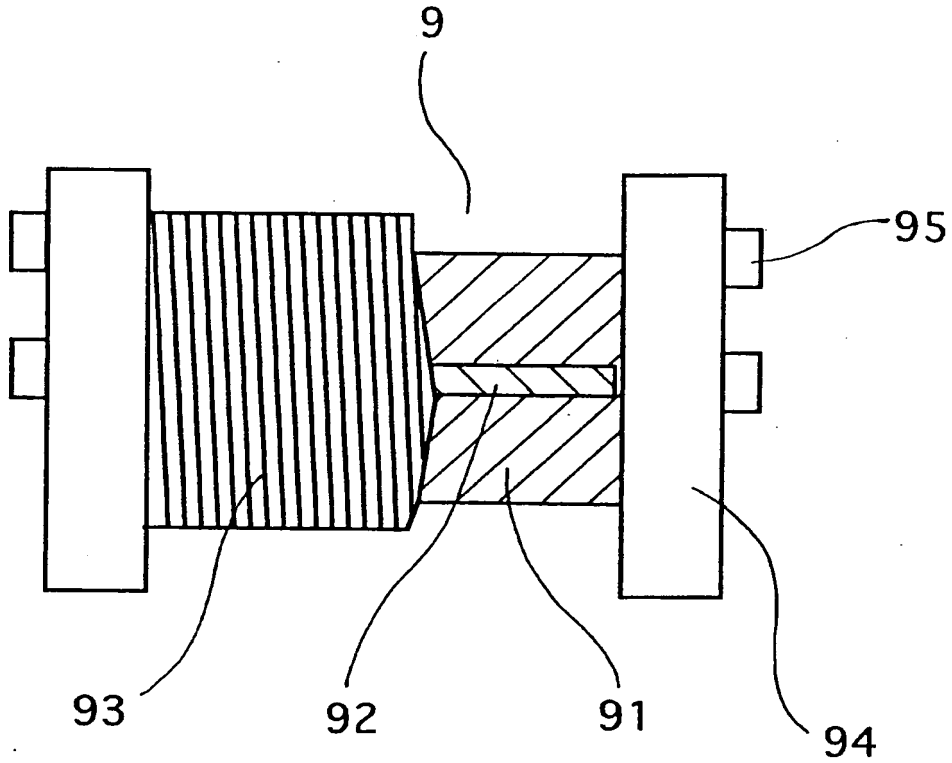
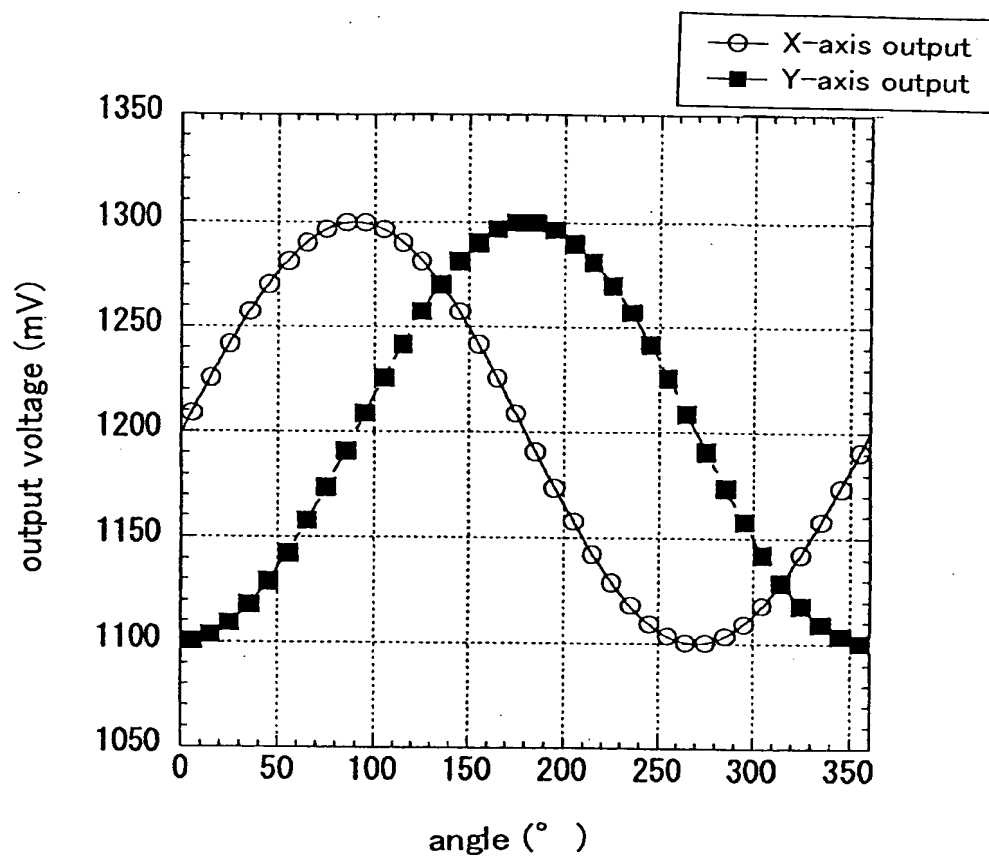
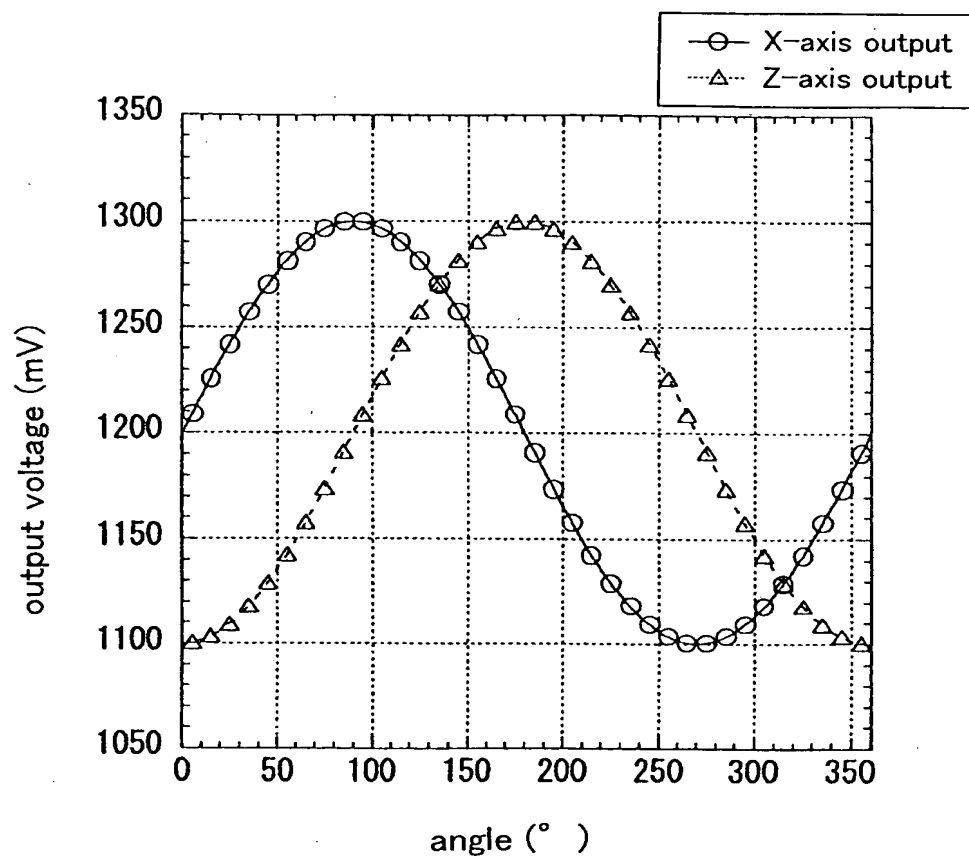


FIG. 13



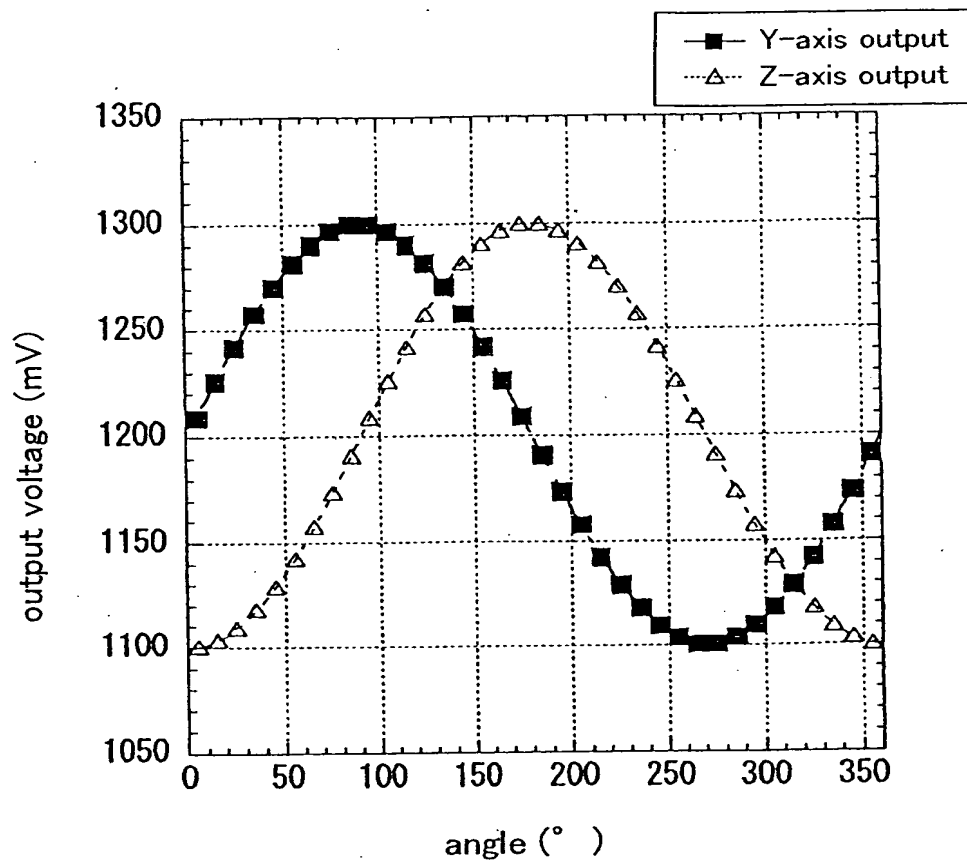
characteristic of X-axis and Y-axis

FIG. 14



characteristic of X-axis and Z-axis

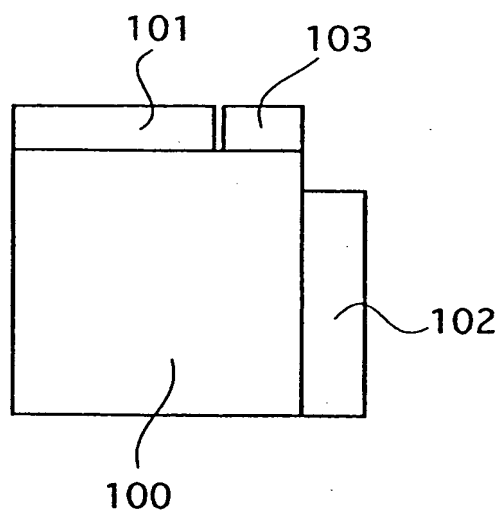
FIG. 15



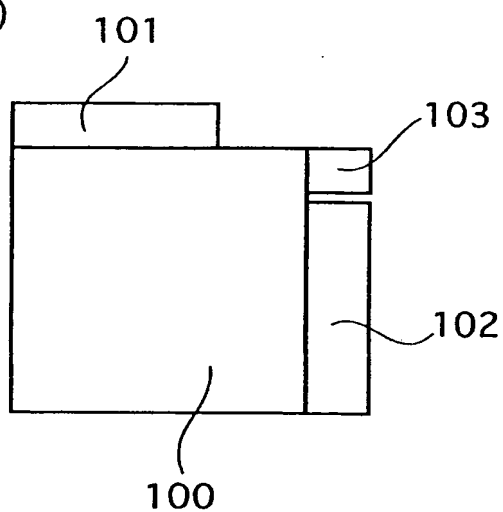
characteristic of Y-axis and Z-axis

FIG. 16

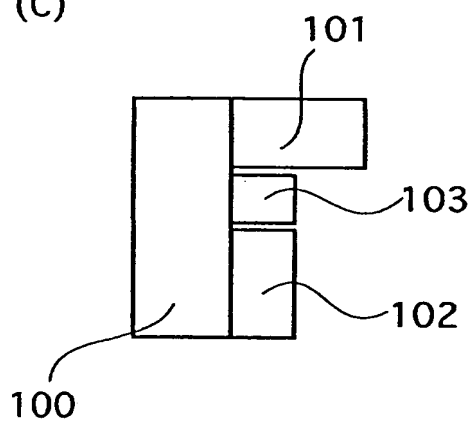
(A)



(B)



(C)



(D)

